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AUTHOR Mattoon, Joseph S.
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ABSTRACT

Differences in learners' control decisions in computer-assisted learning were studied during part task versus whole task practice. The criterion task was chosen for its relevance to air crew training problems. Forty-one male and female undergraduates participated in a computer simulation task estimating the location and orientation of target aircraft on the computer screen. Subjects practiced parts of the task or the whole task and were tested on the complete task. The part-task practice broke the task into components that could be introduced separately and then combined progressively. Whole task practice presented the task in its entirety to maximize the similarity between the practice and criterion task. Overall results favor the part-task practice treatment. Descriptive data on response time and the number of trials indicate that part-task treatment subjects engage in more practice. Part-task learners may more easily see improvements in their understanding and performance when only portions of the task are presented. One figure is included. There is a 22-item list of references. (SLD)

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# LEARNER CONTROL AND PART/WHOLE-TASK PRACTICE METHODS IN INSTRUCTIONAL SIMULATION

## Introduction and Review of the Literature

One of the most powerful capabilities of computer-assisted instruction (CAI) is the variety of formats available for delivering interactive practice. Practice is the main component of instruction that gives rise to improved performance (Phye, 1986), but learners' capability to master knowledge and skill criteria is dependent on the type of tasks performed during practice activities.

Practice is especially important for developing complex skills. Complex skill refers to the ability to perform a number of tasks together to accomplish a single goal. Practice that engages learners in portions of the task independently is referred to as part-task practice, and practice that requires the learner to perform the entire task is called whole-task practice (Gropper, 1983). Wightman and Lintern (1985) define part-task practice as "...practice on some set of components of a whole task as a prelude to practice of or performance on the whole task" (p. 267). Advantages have been found for both part- and whole-task practice formats.

Comparisons have been made between part- and whole-task practice formats since the beginning of the 20th century. In a review of this research, Naylor (1962) concludes that studies prior to 1932 showed little difference between the two practice formats, but later findings suggest that difficulty of a task and its degree of organization can determine which type of practice will be most effective. Task organization is the degree of interdependency among internal components of a complex task. Naylor (1962) defines an organized task as one that has multiple components that interact so that the execution of one component effects another. For example, student pilots must learn how to simultaneously read digital and analog information from radar displays to identify the position and direction of flight of approaching aircraft. Failure to correctly interpret either the digital or the analog information will cause the pilot to loose track of the approaching aircraft (Lahey & Boyer, 1990). After summarizing the results of 50 studies, Naylor (1962) concluded that whole-task practice is most effective for organized tasks that are difficult to master.

Most empirical findings have shown whole-task practice to be more effective for complex tasks (Naylor, 1962; Stammers, 1982; Wightman & Lintern, 1985), but a group of recent experiments have demonstrated greater effectiveness for certain types of part-task formats (Fabiani, Buckley, Gratton, Coles, Donchin, & Logie, 1989; Frederiksen & White, 1989; Mane, Adams, & Donchin, 1989; Newell, Carlton, Fisher, & Rutter, 1989). In these studies multiple experiments were conducted to examine learners' performance on controlling a simulated space craft. The perceptual and information processing components of this task bear a close resemblance to real aviation tasks. Although the task is highly organized and difficult, Fabiani et al. (1989), Frederiksen and



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White (1989), Mane et al. (1989), and Newell et al. (1989) found part-task practice to be superior to whole-task practice. These findings conflict with most previous part-whole task comparisons and suggest that particular forms of part-task practice may be better than whole-task practice for tasks that are organized and challenging to learn.

Many strategies can be employed in CAI to control instructional events. There are two basic types of instructional control, learner control and computer control. Learner-controlled CAI enables learners to adapt the instruction to suit their perceived needs. In contrast, computer-controlled CAI delivers instruction according to a preset plan (fixed control) or alters instructional events as a function of an individual's behavior (adaptive control). A review of the literature did not reveal any studies that have examined the effect of part/whole-task practice on learners' decisions in learner-controlled CAI.

Providing learners with descriptive information on their progress toward performance criteria helps them make effective decisions during the learning process. Tennyson (1981) and Tennyson and Buttrey (1980) have demonstrated that learners can effectively choose the type and amount of practice they need when given an ongoing report of their performance during a CAI lesson. Schloss, Wisniewski, and Cartwright (1988) have come to similar conclusions about learner-controlled practice activities. In their study, undergraduates read a portion of the course content and answered practice questions on the topic of special education via a CAI lesson. They received cumulative performance feedback to help them decide whether to review lesson material or move on to new material. The feedback consisted of each individual's number of correct answers for the most recent five questions and the number of times they had chosen to review lesson content following an incorrect answer. Learner control subjects performed better than computer control subjects on posttest questions that were included as practice items in the lesson but more poorly on questions that were indirectly based on lesson content. This research suggests that learners can effectively choose the type and amount of practice needed if they are provided with information that is directly applicable to executing the criterion task.

Steinberg (1989) lists two possible benefits of learner control combined with performance feedback: (a) A CAI program can provide the kind of ongoing information learners need to correct errors during practice. (b) Such information enables learners to "fine tune" their control decisions according to each individual's perception of his/her current needs. In summary, two conditions probably need to be met for effective learner control: (a) Learners should be provided with ongoing feedback on their progress toward the criterion. (b) The feedback must clearly communicate learners' strengths and weaknesses relative to the criterion task.

The effects of instructional control or practice are dependent on learners' familiarity with the subject matter (Hannafin, 1984; Gay, 1986), their ability (Duchastel, 1986; Goetzfried & Hannafin, 1985), and task difficulty

(Steinberg, 1989). Breaking a task down into its individual components for the purpose of part-task practice may help learners deal with unfamiliar, difficult tasks by reducing attentional requirements and load on working memory during initial skill acquisition. In a whole-task practice program, learners must divide their attention among the task components, judge their ability to execute each component, and learn how each component relates to the task as a whole. It is likely that control decisions are more difficult during whole-task practice due to the increased complexity of dealing with the entire task. In contrast, part-task practice enables learners to initially focus on smaller portions of the task and gradually build their familiarity and competence until they are able to execute the task in its entirety. This may facilitate learners' decisions concerning the amount of practice they require on specific components of the criterion task.

Gradually encouraging learners to make control decisions as they acquire more knowledge and skill may accelerate their ability to perform a complex task, independent of instructional cues. This goal can probably be best accomplished by "progressive part-task" practice, whereby learners progressively perform additional task components until they are able to execute the entire task (Frederiksen & White, 1989).

In aircrew training programs, pilots must learn how to interpret information from many types of cockpit instruments. These instruments display words, numbers, and symbols that indicate the state of an aircraft and surrounding airspace. Situations can change rapidly due to the speed of flight, and this requires pilots to repeatedly interpret complex displays to guide their decisions for controlling the aircraft. The head–up display (HUD) provides digital and analog information that is used to identify the location and orientation (direction of flight) of approaching aircraft that may not be visible due to their distance or weather conditions. Pilots must accurately interpret the HUD for purposes of air-to-air interception or avoidance of possible collision. Lahey and Boyer (1990) demonstrated that learners with no previous training could learn how to interpret the HUD by practicing with a CAI simulation. However, subjects required about 400 whole-task practice trials to attain the criterion performance.

Reading the HUD is a complex and challenging task because it simultaneously presents three different parameters that consist of both digital and analog information. Additionally, the task of estimating the location of "target" aircraft and determining their orientation (direction of flight) is an organized task because pilots' estimation of one parameter can affect the accuracy of their estimation of another. Describing the effect of part/whole-task practice on developing display interpretation skills may facilitate the design of effective training for this task and similar task domains.

The purpose of this study is to identify differences in learners' control decisions during part- versus whole-task practice. The criterion task was chosen for its relevance to current aircrew training problems of the U. S. Air

Force and the aviation training community.

## Method

### Subjects

Forty-one male and female undergraduate volunteers from two public universities in the southwestern United States participated in the experiment.

### Materials

A CAI program was developed with HyperCard software for Macintosh computers with 12 inch screens. The instructional content was developed and evaluated during a previous study (Mattoon, Klein, & Thurman, 1991). Each program delivered a lesson on using the computer mouse, a lesson and practice activity on interpreting a simulated HUD, and a criterion test. All demographic and performance data was recorded on 3.5 inch floppy disks during the experiment. Subjects controlled the pace of the CAI and executed practice tasks using a standard Macintosh mouse. The major parts of the CAI are described below in the sequence that each was presented during the experiment.

#### Computer Mouse Lesson

A lesson on using the mouse was presented first to teach subjects how to activate HyperCard "buttons" (graphic objects that control the CAI), and manipulate an icon used during practice and test activities. The lesson consisted of a practice exercise and a ten-item test. Subjects' response time was recorded for placing the icon at designated locations and rotating it to specific orientations.

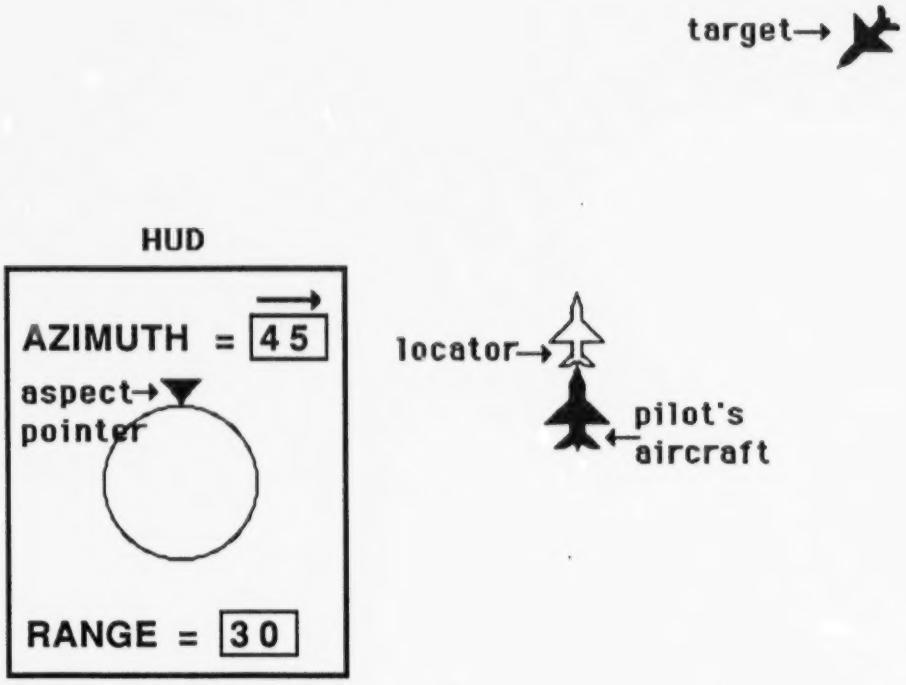
#### HUD Lesson

A lesson on interpreting the simulated HUD demonstrated how to estimate the location and orientation of simulated target aircraft on the computer screen. Three aircraft-shaped icons were used in the lesson: (a) The "pilot's aircraft" remained at a fixed location and orientation at the bottom of the screen. (b) The "locator" (white aircraft) was placed at various locations and orientations to demonstrate how to estimate targets. (c) A variety of "target" icons (black aircraft) demonstrated the correspondence between target parameters shown on the HUD and the location and orientation of targets.

The lesson covered three target parameters that are displayed on the HUD: (a) Range is the linear distance of a target from the pilot's aircraft. Range was displayed on the simulated HUD as a whole number from 15 to 40. (b) Azimuth is the angular distance the target lies to the left or right of the pilot's aircraft. Azimuth was displayed on the HUD as a whole number from five to 60 degrees in five-degree increments. An arrow displayed above the azimuth value indicated a right or left azimuth position relative to the pilot's aircraft. (c) Aspect refers to a target's orientation with respect to the pilot's aircraft. Aspect was represented on the HUD by the position of the "aspect pointer" along the circumference of a circle.

The HUD lesson consisted of 15 "pages" of instruction (text and graphics appearing on the screen at one time). The lesson described how to estimate target range, azimuth, and aspect by placing the locator on the screen at specific

locations and orientations. The figure below shows a target located at a range of 30 nautical miles, with a right azimuth of 45 degrees, and the aspect pointer indicates that the target is moving straight toward the pilot's aircraft.




Practice Exercises

The practice exercises contained 24 different values for each target parameter. One or more parameters were displayed on the HUD for each target, and the sequence of values was repeated when the subject chose to complete more than 24 practice trials. The subjects' task was to study the information on the HUD and position the locator on the screen to estimate target location and orientation. The locator was moved by placing the mouse curser over the top of the locator, holding the mouse button down, and "dragging" the locator across the screen. Its orientation was changed by activating one of two "rotate buttons." One button rotated the locator clockwise and the other, counterclockwise. After positioning the locator, the target appeared at the correct location and orientation.

Part-Task Treatment

The part-task practice treatment included six exercises. The first exercise only required estimates of target range, and the HUD showed only the range parameter. A guideline extending from the pilot's aircraft to the top of the screen designated target azimuth. The locator's aspect was fixed at a vertical angle throughout this exercise. This enabled subjects to estimate target range independent of azimuth and aspect.

The second exercise required estimates of target azimuth, independent of range and aspect, which were fixed throughout the exercise. The task was to move the locator along a curved guideline to a point that corresponded to the target azimuth. The guideline designated target range, and the HUD displayed only azimuth.

The third exercise required estimates of both range and azimuth. The task was to position the locator on the screen to estimate range and azimuth. The HUD displayed only range and azimuth, and the locator's aspect remained fixed.

The forth exercise required estimates of target aspect. The locator appeared at the correct location (range and azimuth), and the task was to rotate it to the estimated target aspect.

The fifth exercise required estimations of both azimuth and aspect. The task was to move the locator along a curved guideline (designating target range) to estimate azimuth, and rotate it to estimate aspect.

The sixth exercise required subjects to estimate range, azimuth, and aspect on each trial. The task was to position the locator on the screen to estimate range and azimuth, then, rotate it to estimate aspect.

On each practice trial, the target appeared at the correct location and orientation after it was positioned. Additionally, verbal instructions were printed at the bottom of the screen to direct subjects' attention to the particular parameter(s) of the current exercise.

Whole-Task Treatment

Whole-task practice consisted of a single practice exercise. The exercise was identical to the sixth part-task exercise except for the feedback. Verbal feedback identified the parameter that was estimated with the greatest accuracy and the parameter that was estimated with the least accuracy after each response. Additionally, one of the guidelines (that designated range or azimuth) appeared on the screen to focus subjects' attention on the parameter with the greatest error. In other words, instead of practicing parts of the target-estimation task, whole-task subjects completed the entire task but their attention was directed to their performance on each part.

HUD Posttest

The HUD test consisted of 30 targets to estimate. The target-estimation task was equivalent to the whole-task practice exercise except that no feedback on subjects' performance was provided until the end of the test. Subjects were urged to estimate each test target as "accurately and as quickly as possible."

They completed three sample targets prior to the test and were encouraged to respond more quickly if their response time exceeded 30 seconds. After each target estimate, the screen displayed the message, "get ready for the next target," three seconds prior to changing target parameters on the HUD. Test targets had different combinations of parameters than those used on the practice so that no targets were repeated.

## Procedures

Two different versions of the CAI delivered either part- or whole-task practice. The programs assessed target estimations and computed a score for practice and test performance that ranged from zero to 100 points. The score was displayed after every fifth practice trial and represented subjects' average degree of accuracy for the most recent five target estimations.

Points for each parameter estimate were computed by subtracting the number of "error units" from 100. Error units were computed separately for each target parameter. Error in range consisted of the difference between the locator's and the target's linear distance from the pilot's aircraft. Distance was measured in screen pixels. Error for azimuth and aspect estimations was measured in degrees. Error units were derived by multiplying the error by a specific factor. For example, range error was multiplied by a factor of 1.5.

The factors for error units ensured that points earned for each parameter were about equally challenging. When more than one target parameter was estimated, points were averaged across target parameters to reflect the overall accuracy of target estimates.

A minimum and maximum number of practice trials were set for both part- and whole-task treatments. Subjects in the part-task treatment completed a minimum of five trials in each exercise to ensure that they viewed their score at least once. They were able to complete up to 40 trials. An equivalent amount of practice was computed for the whole-task CAI. This was done by summing the portions of the target-estimation task for each part-task exercise and multiplying by five (minimum number of part-task trials). For example, each of the part-task exercises includes 1/3, 1/3, 2/3, 1/3, 2/3, and 3/3 of the target-location task, respectively. A part-task trial completed in each exercise was roughly equivalent to 10/3 whole-task trials (10/3 x 5 = 16.7 = 17 trials). The maximum number of trials for whole-task practice was computed as 10/3 * 40 = 133 trials.

Subjects were assigned to one of the two treatments in the order they arrived at the computer site. About 15 subjects participated in the experiment at one time due to the limited capacity of the computer site. All subjects completed the mouse lesson and HUD lesson, respectively, before beginning practice.

## Results and Discussion

A multivariate analysis of covariance (MANCOVA), with response time on the mouse test as the covariate, did not reveal a significant treatment effect for

test score and response time on the test ($p>.05$). However, the difference in means for male and female indicated a possible effect for gender. The treatment groups were collapsed, and a second MANCOVA revealed a significant multivariate effect for gender ($F(2,37)=4.46$, $p<.05$). Univariate tests revealed that males exceeded females on test score ($M=70.7$ vs. $M=59.0$, $F(1,38)=7.21$, $p<.05$) and that males estimated targets more quickly than females ($M=18.6$ vs. $M=23.1$ seconds, $F(1,38)=4.77$, $p<.05$). Since there were more female (n=19) than male subjects (n=12), all additional tests were conducted using only female subjects' data.

A third MANCOVA revealed a multivariate treatment effect ($F(2,25)=4.20$, $p<.05$). Univariate tests showed that the part-task group performed the task more quickly than the whole-task group ($M=16.9$ vs. $M=20.6$, $F(1,26)=5.11$, $p<.05$), but both groups received about the same test score ($M=59.1$ vs. $M=58.9$, $F(1,26)=0.19$, $p=.67$). Although a few seconds delay in most problem-solving situations does not have serious consequences, even a small delay in performing a critical aviation task during flight can have disastrous results. Therefore, speed of task execution is an important metric of performance.

There appear to be some differences in practice behavior that may have contributed to the treatment effects. Part-task subjects completed a mean of 9.0, 7.6, 8.8, 11.9, 7.4, and 6.9 practice trials for each of the six exercises, respectively. Multiplying each mean by the proportion of the target-estimation task performed in each part-task exercise (1/3 x 9.0 + 1/3 x 7.6 + 2/3 x 8.8 + 1/3 x 11.9 + 2/3 x 7.4 + 3/3 x 6.9) provided an estimate of the mean number of times part-task subjects executed the entire task during practice ($M=27.3$) compared to the mean number of whole-task trials ($M=17.7$) completed by the whole-task group.

The time subjects spent responding to practice trials was approximated by multiplying mean response time by the mean trials completed for each respective exercise. Part-task subjects spent about 15.2 minutes responding to practice items compared to 11.3 minutes for whole-task subjects. Unfortunately, the program did not record the time subjects spent examining feedback, so total time spent on practice could not be compared. However, observations by the experimenter indicate that subjects in both treatments appeared to spend about the same amount of time examining feedback.

Evidently, the part-task practice induced subjects to engage in more practice prior to the test. It would be expected that subjects would tend to practice until they were relatively satisfied with their scores. For example, if part-task practice scores were lower than whole-task scores, it would explain why subjects practiced longer. However, the difference in mean practice scores did not reach a significant level ($F(1,27)=2.22$, $p=.11$). In fact, the part-task mean score ($M=60.5$) appeared to be higher than the whole-task mean score ($M=53.0$).

Part-task subjects tended to perform the whole-task practice trials (in the 6th exercise) more quickly than the whole-task group ($M$=24.6 vs. $M$=38.2 seconds, $F(1,27)=9.45$, $p<.01$). This suggests that the first five part-task exercises prepared subjects for the criterion task by boosting their ability and/or confidence and is likely the reason for their superior speed on the test.

## General Discussion

The part- and whole-task treatments represent different instructional strategies for teaching complex skills. In this experiment part-task practice exercises were designed to meet two general goals: (1) Break the task down into components so that each component can be introduced separately to reduce information processing load during initial knowledge and skill acquisition. (2) Progressively combine components of the task (e. g., range and azimuth estimation) in a way that emphasizes their degree and type of interdependence to facilitate learners' integration of the task as a whole. Whole-task practice also had two general goals: (1) Present the task in its entirety to maximize the similarity between the practice and criterion task, and therefore, facilitate the transfer of skill from guided instruction to independent performance. (2) Emphasize the learners' strengths and weaknesses to focus their attention on the appropriate task components and facilitate error correction.

Overall results were in favor of the part-task treatment because interpreting an instrument more quickly is equivalent to performing at a higher level of skill in real-world situations. Descriptive data on response time for practice targets and number of practice trials completed indicate that the part-task treatment subjects engaged in more practice.

Part-task practice may encourage learners to practice more before a test than whole-task practice. If so, it is probably because learners can more easily see improvements in their understanding and performance when only portions of the task are presented. This would reduce frustration and encourage greater effort on practice activities.

Prescriptions for developing instructional control strategies and other instructional features for CAI are especially lacking for training complex skills. However, the need for developing CAI simulation to teach these skills in military and commercial aviation is increasing (Andrews, 1988; Munro, Fehling, & Towne, 1985; Reigeluth & Schwartz, 1989). Andrews (1988) explains that training simulations have been traditionally designed with a greater emphasis on faithfully representing real tasks and environments than on instructional effectiveness. Consequently, training simulations lack instructional guidance and require learners to decide the amount and type of practice they need to competently perform complex tasks.

Further research needs to flesh out the differential effects of part- and whole-task formats on learners' behavior and cognition during practice. Differences in the amount of effort learners expend on practice, their perceptions of the task, and their judgments of their ability to understand the

material and develop greater skill need to be examined. There is little knowledge about learners' ability to make instructional-control decisions when engaged in complex tasks. Also, the effects of gender need to be examined in terms of differences in ability for performing specific types of complex tasks and the influence of instructional control in part/whole-task practice. Finally, instructional control should be incorporated into part/whole-task experiments as an independent variable to examine the differences in computer- and learner-controlled practice.

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